Space Weather Technical Forecast

Issued on Saturday, 11 May 2024 at 00:30 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G4 (Severe) Geomagnetic storms expected 11 May with a high chance of further G5 (Extreme) intervals. Further R3 (Strong flares) likely.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has remained High in the past 24 hours, with X-ray activity recorded at GOES16 showing frequent M-class activity, peaking with an X3.9 from AR3664 at 10/0706UTC. There are currently eight sunspot groups on the disc, with large and complex Ex-AR3663 now no longer visible on the northwestern solar horizon. New regions appeared in the southeast disc, but as small features.

AR3664 is by far the largest and most complex region on the disc, as has been the case for recent days. It currently presents as a Zurich Fkc with Mt Wilson Beta-Gamma-Delta classification. Although growth of the region has slowed, there has been consolidation of the broader penumbral area and notable relative movement between the various mixed polarity spots, presenting large magnetic shear and further potential for large flares. There are numerous Mt Wilson deltas present. The remaining regions on the visible disc are much smaller and more magnetically simple.

The X3.9 and M5.9 flares of AR3664 on 10 May both resulted in CMEs that are Earth directed. The latter is much slower and awaiting analysis. The former is expected to arrive at Earth late on Day 1 (11 May) or early Day 2 (12 May). A filament eruption from the south-centre disc does not appear to have resulted in an energetic CME.

Solar Wind / Geomagnetic Activity: Solar winds, as observed by ACE at L1, were at slightly elevated levels for much of the period, but increased following the passage of the first CME at 10/1639 UTC. Speeds jumped to strong levels, around 700km/s, with a further spike observed with the arrival of the second CME after 10/2139 UTC. Peak speeds of 804km/s (very strong) were observed at 10/2212 UTC. Solar wind density was largely at average to below average levels early in the period, but increased ahead of and following both CME arrivals, reaching above average levels and peaking briefly at well above average levels at 10/1917 UTC (57ppcc). The IMF was at weak levels until the passage of both CMEs. Very strong IMF values were recorded ~50nT following the first CME and ~70nT at peak following the second arrival. The north-south component was weakly variable early on, but predominantly very strongly negative (southward) Bz following both CME arrivals, ranging between +63/-50nT. The phi angle was highly variable throughout between positive (away from the Sun) and negative (towards the Sun) sectors.

The net result of the above solar wind measures was Quiet to Unsettled geomagnetic activity early in the period, increasing to G4/Severe (Kp8) between 10/1500-2100 UTC, then a G5/Extreme (Kp9) interval 10/2100-10/2400 UTC.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) observed at GOES18 showed an upward trend in the wake of recent strong flares, rising to S2/Moderate storm levels at peak immediately following the first CME arrival on 10 May. Proton flux reduced

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to S1/Minor Storm levels thereafter.

High energy electron flux (greater than 2MeV) observed at GOES16 was at normal background to moderate levels. The associated 24-hour fluence was well below the Active threshold. Observed fluence at 11/0001 UTC was 2.14e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Further X-class flares are likely in the coming days with frequent M-class flares expected, primarily from AR3664, but perhaps also contributed to from new eastern solar horizon arrivals.

Solar Wind / Geomagnetic Activity: Recent CME arrivals have significantly increased geomagnetic activity and solar wind speeds (strong) and further CMEs are expected to follow in the coming days. Two large flares from AR3664 on 09 May resulted in Earth-directed CMEs. The faster, second CME is forecast to merge with the preceding CME resulting in a combined front arriving late Day 1 (11 May) or early Day 2 (12 May). Another much slower CME was observed leaving the sun following another large flare of AR3664 on 10 May. This is awaiting analysis, but likely has an Earth-directed component, perhaps arriving at the end of the forecast period.

Coronal hole enhancements during the period are expected to be more muted compared to ongoing and forecast CME effects. A minor coronal hole enhancement is possible from late Day 1 (11 May) or early Day 2 (12 May), although this feature may well have opened too late for any arising fast wind to intersect the Earth, which would delay the inbound fast wind to the larger and more intense coronal hole later on Day 2 (12 May). A small coronal hole in the southern hemisphere may also connect with Earth in a similar timeframe.

Geomagnetic activity is expected to be at G4/Severe (Kp8) levels initially on Day 1 (11 May) with high chance of G5/Extreme storm conditions early in the period. Activity should erratically subside on Day 1 (11 May), but become enhanced again following the combined arrivals of the two CMEs late Day 1 (11 May), or more likely early Day 2 (12 May). Peak G2/Moderate storming is most likely, but with a chance of G3-G4/Strong-Severe levels of activity. Activity should further wane from later on Day 2 (12 May), with reduced risk probabilities on Days 3 and 4 (13 and 14 May), however confidence at the end of the period is low and the forecast may change should further large Earth-directed CMEs occur.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV) is at S1/Minor Storm levels and should be maintained into Day 1 (11 May) at least, with a somewhat uncertain decline projected in the absence of any further significant flaring from AR3664. The region is, however, moving into a more favourable location for proton response in the coming days. There is a chance of S3/Strong or greater levels on Day 1 (11 May) reducing to a slight chance on the remaining days, although this could change following any further large flares from AR3664.

High energy electron flux is forecast to be at normal background to Moderate levels throughout, with associated fluence expected to remain well below the Active (1e8 integrated pfu) threshold.

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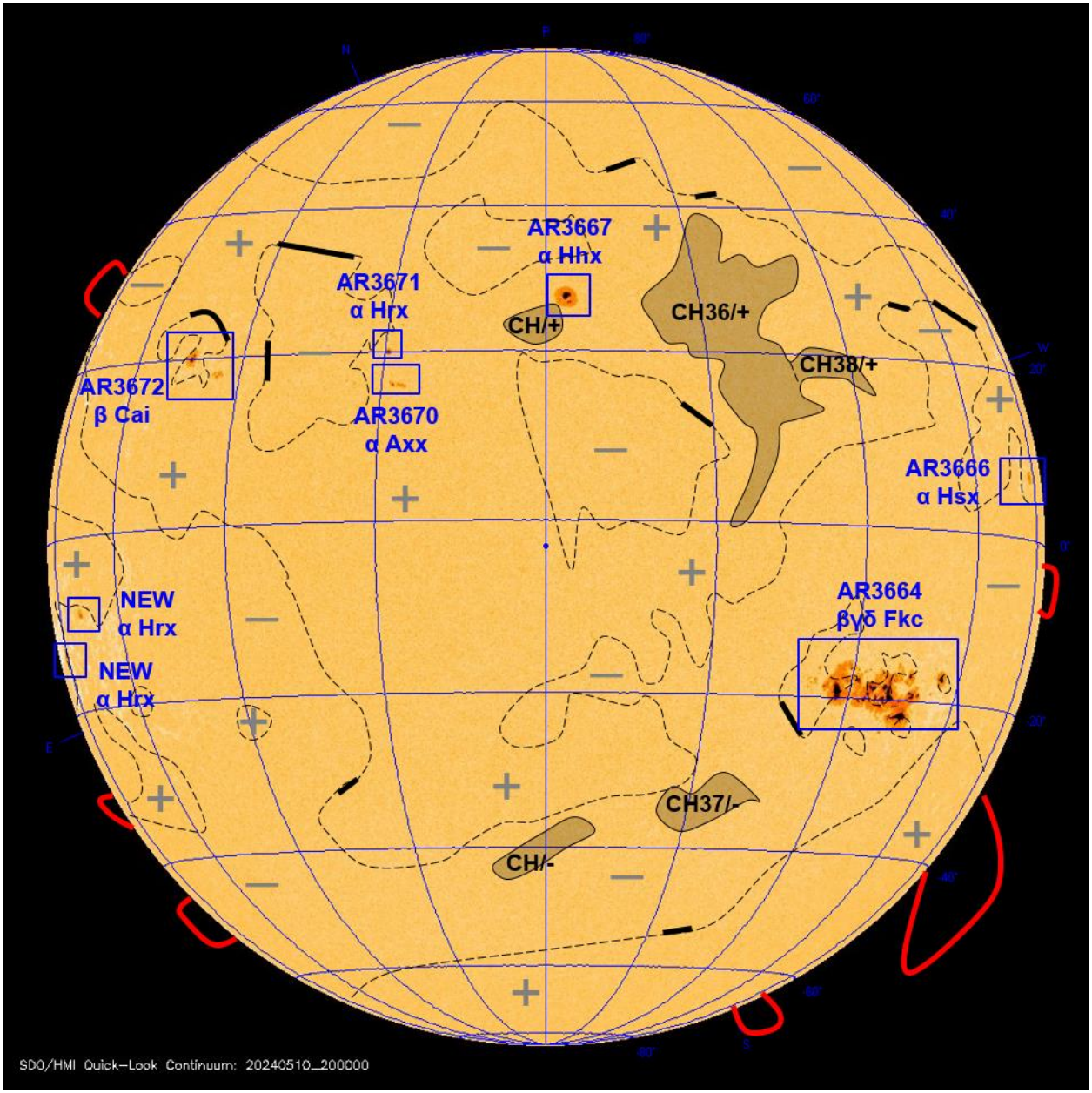
Figure 1. Solar Analysis Valid 10/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Multiple CME arrivals were detected at L1 on 10 May, though there are two or potentially three further Earth-directed CMEs expected in the coming days.

A CME associated with the X1.1 flare of AR3664 at 09/1743 UTC, is expected to be 'swept up' by the faster CME from the X3.9 flare of the same region at 10/0654 UTC. This is expected to result in a combined arrival at Earth late on Day 1 (11 May) or more likely early Day 2 (12 May). Another CME was observed leaving the sun following the M5.9 flare of AR3664 at 10/1411 UTC. This is awaiting analysis, but appears much slower, perhaps arriving at the end of the forecast period.

Other drivers of geomagnetism from coronal hole enhancements are expected to be masked and pale in comparison to the ongoing CME effects. A minor coronal hole enhancement is possible from late Day 1 (11 May) or early Day 2 (12 May), although this (CH38/+) may well have opened too late for any arising fast wind to intersect the Earth, which would delay the inbound fast wind to the larger and more intense CH36/+ later on Day 2 (12 May). Small CH37/- in the southern hemisphere may also connect with Earth in a similar timeframe.

Geomagnetic activity is expected to be at G4/Severe (Kp8) levels initially on Day 1 (11 May) with likely peak G5/Extreme storm conditions. Activity should erratically subside on Day 1 (11 May), but become enhanced again following the combined arrivals of the two CMEs late Day 1 (11 May), or more likely early Day 2 (12 May). Peak G2/Moderate storming is most likely, but with a chance of G3-G4/Strong-Severe levels of activity. Activity should further wane from later on Day 2 (12 May), with reduced risk probabilities on Days 3 and 4 (13 and 14 May), however confidence at the end of the period is low and the forecast may change should further large Earth-directed CMEs occur.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	100	95	50	30
Strong	G3	Yes	100	50	10	5
Severe	G4	Yes	95	30	5	1
Extreme	G5	Yes	50	5	1	1

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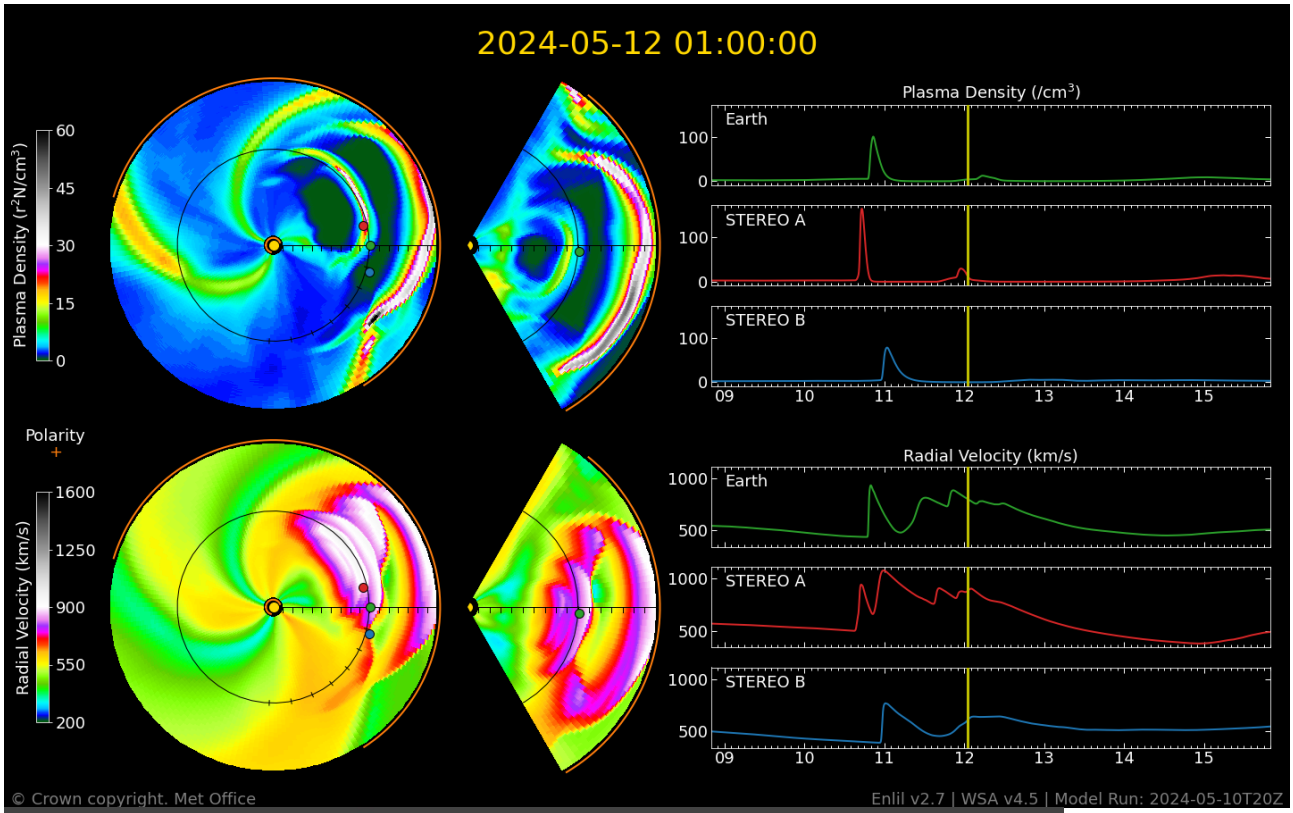
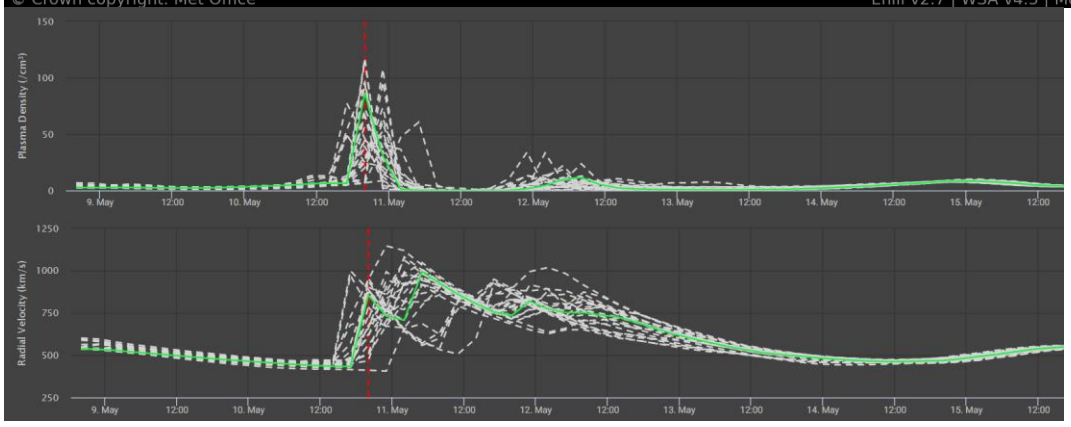
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
09/2219	Full	AR3664	SW	888 km/s	12/0100 UTC	Swept up by second CME
10/0950	Full	AR3664	SW	1170 km/s	12/0100 UTC	Sweeps up first CME

Figure 2: Latest MOSWOC Enlil and Ensemble forecast





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Met Office Space Weather Technical Forecast

Radio Blackouts - X-Ray Flares:

Solar activity for much of the past UTC working week has been dominated by the large and complex regions Ex-AR3663 and AR3664. Ex-AR3663 has now rotated over the northwest horizon, though still poses a slight risk for further significant flares in the near-term. AR3664 will persist on the visible disc until the end of day 4 (14 May).

There are numerous signs of another large sunspot region near the southeastern solar horizon. This is visible on both far-side helioseismographs as well as EUV imagery (e.g. AIA171) and expected returning Carringtons for the period. The extent to which this compensates for the loss of Ex-AR3663 is not known, however AR3664 provides the bulk risk of significant flares on its own, and is certainly the dominant consideration for the period.

All considered, there is an initial slight decrease in the risk of R3 given the departure of Ex-AR3663, however the fact X-ray flux has resided within M-class for much of the period means the Expected risk of R1/R2 remains largely unchanged. Any contribution from the eastern solar horizon will be factored in as and when regions present for analysis.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	95	95	95	95
Very Active	R3 to R5 X Class	Yes	60	50	50	50

Solar Radiation Storms - (High Energy Protons):

High energy proton flux (greater than 10MeV) observed at GOES18 has increased in response to active flaring of AR3664 and the arrival of multiple CMEs on 10 May. S1/Minor Storm levels should be maintained into Day 1 (11 May) at least, with a somewhat uncertain decline projected in the absence of any further significant flaring from AR3664. The region is, however, moving into a more favourable location for proton response in the coming days. There is a chance of S3/Strong or greater levels on Day 1 (11 May) reducing to a slight chance on the remaining days, although this could change following any further large flares from AR3664.

Radiation Storms	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ S1	Yes	100	80	60	40
Very Active	≥ S3 *	No	20	15	10	5

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

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High Energy Electrons Event (≥ 2MeV):
High energy electron flux at GOES16 is at normal Background levels, and is expected to remain at or near this level throughout given the number of inbound CMEs and the likely sustained pressure on the Van Allen belts sweeping them inside GEO for some time.
Overall, the 24-hour integrated electron fluence is forecast to remain well below the Active (1e8 integrated pfu) threshold. The Met Office REFM is not considered to offer useful guidance in the coming days by anything other than chance given the CME-dominated forecast.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^{8}$	No	1	1	1	1
Very Active	≥ 2 MeV ≥ $1x10^{9}$	No	1	1	1	1

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